National Aeronautics and Space Administration

Space Launch System (SLS)
Safety, Mission Assurance, and Risk Mitigation

AIAA Civil Space 2013
February 13, 2013

Todd May, Program Manager
NASA Marshall Space Flight Center

Space Launch System

The Future of Exploration

The Space Launch System [will] be the backbone of its manned spaceflight program for decades. It [will] be the most powerful rocket in NASA's history…and puts NASA on a more sustainable path to continue our tradition of innovative space exploration.

President Obama's Accomplishments for NASA
May 22, 2012

SLS Driving Objectives

- **Safe**
  - Human-rated to provide safe and reliable systems for human missions
  - Protecting the public, NASA workforce, high-value equipment and property, and the environment from potential harm
- **Affordable**
  - Maximum use of common elements and existing assets, infrastructure, and workforce
  - Constrained budget environment
  - Competitive opportunities for affordability on-ramps
- **Sustainable**
  - Initial capability: 70 metric tons (t), 2017–2021
    - Serves as primary transportation for Orion and exploration missions
    - Provides back-up capability for crew/cargo to ISS
  - Evolved capability: 105 t and 130 t, post-2021
    - Offers large volume for science missions and payloads
    - Modular and flexible, right-sized for mission requirements

Flexible Architecture Configured for the Mission

Block Upgrade Approach

INITIAL CAPABILITY, 2017–21

EVOLVED CAPABILITY, Post-2021

70 t
320 ft

130 t
384 ft

Launch Abort System
- ***Orbital Sciences Corp.***

Orion Multi-Purpose Crew Vehicle (MPCV)
- ***Lockheed Martin***

Interim Cryogenic Propulsion Stage
- Early flight certification for Orion
- Flexible for a range of payloads
- ***Boeing***

Core/Upper Stage
- Common design, materials, & manufacturing
- ***Boeing***

Avionics
- Builds on Ares software
- ***Boeing***

Evolutionary Path to Future Capabilities
- **Minimizes unique configurations**
- **Allows incremental development**
- ***Advanced Development contracts awarded in FY13***

5-Segment Solid Rocket Boosters
- Upgrading Shuttle heritage hardware
- ***ATK***

Fairings (27.5' or 33')
- Right-sized for the payload
- Industry input received in FY13

J-2X Upper Stage Engine
- Builds on Apollo Saturn J-2 heritage
- ***Pratt & Whitney Rocketdyne***

Advanced Boosters
- Competitive opportunities for affordable upgrades
- ***Risk-reduction contracts awarded in FY13***

RS-25

Core Stage Engines
- Using Space Shuttle Main Engine inventory assets
- Building on the U.S. state of the art in liquid oxygen/hydrogen
- ***Initial missions: Pratt & Whitney Rocketdyne***
- ***Future missions: Agency is determining acquisition strategy***

Working with Industry Partners to Develop America's Heavy-Lift Rocket

SLS Program Organization at MSFC

1/09/13

Hard line programmatic
Matrix relationship

Program Manager Todd May

Deputy Manager Jody Singer

Assistant Program Manager Sharon Cobb

Chief Engineer (CE) Garry Lyles

Deputy CE John Honeycutt

Strategic Development Manager Steve Creech (XP01)

Chief Safety Officer (CSO) Rick Burt

Deputy CSO Dan Mullane

Program Integration Manager Mark Richards (XP02)

Procurement Manager Earl Pendley

Program Planning & Control Manager Keith Hefner

Deputy Manager Daryl Woods

Boosters Manager Alex Priskos

Deputy Manager Bruce Tiller

Engines Manager Mike Kynard

Deputy Manager Sheryl Kittredge

Stages Manager Tony Lavoie

Deputy Manager Julie Bassler

Ground Operations Liaison Manager Brian Matisak

Assistant Manager Andy Warren

Advanced Development Office Manager Chris Crumbly

Assistant Manager Fred Bickley

Spacecraft & Payload Integration Manager David Beaman

Vacant

Assistant Manager

Communication Integration

- **Accountability and Responsibility**
  - Strong focus on leadership at all levels
  - Organized to balance functional expertise and cross-functional integration
  - Chief Safety Officer and staff provide guidance, analysis, and oversight/insight
  - Chief Engineer serves as lead designer, with staff focused on technical integration
  - Early integration of production considerations
  - Entire organization focused on stakeholder value

SLS Systems Engineering & Integration Organization	Systems Engineering	Vehicle Management	Structures & Environments	Propulsion	Production	Integrated Avionics & Software	Operations	Test	Safety & Mission Assurance
Program Chief Engineer (CE)	Lead Systems Engineer (LSE)	Discipline Lead Engineer (DLE)	DLE	DLE	DLE	DLE	DLE	DLE	Chief S&MA Officer (CSO)
Stages Element Chief Engineer (ECE)	Element LSE (ELSE)	Element DLE (EDLE)	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	Element CSO (ECSO)
Booster ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Engines ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Integrated Spacecraft & Payload ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Advanced Development ECE									

Safety Risks - Identification and Mitigation

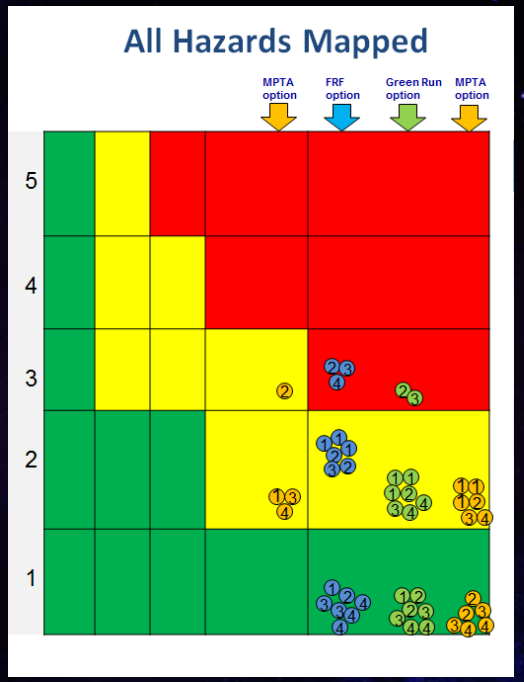
- Qualitative [Hazard Analyses (HA) and Failure Modes and Effects Analysis/Critical Item Lists (FMEA/CIL)] and Quantitative (PRA) tools are used to identify, characterize and mitigate safety risks.

- Probabilistic Risk Assessment (PRA) complements HAs, FMEA/CILs, reliability predictions and abort capabilities to estimate aggregate risk for Loss of Mission (LOM) and Loss of Crew (LOC).

- Safety Assessments are also used to support trade studies.
  - Example: Main Propulsion Test Article vs Green Run vs Flight Readiness Firing Trade study

Safety Review Process

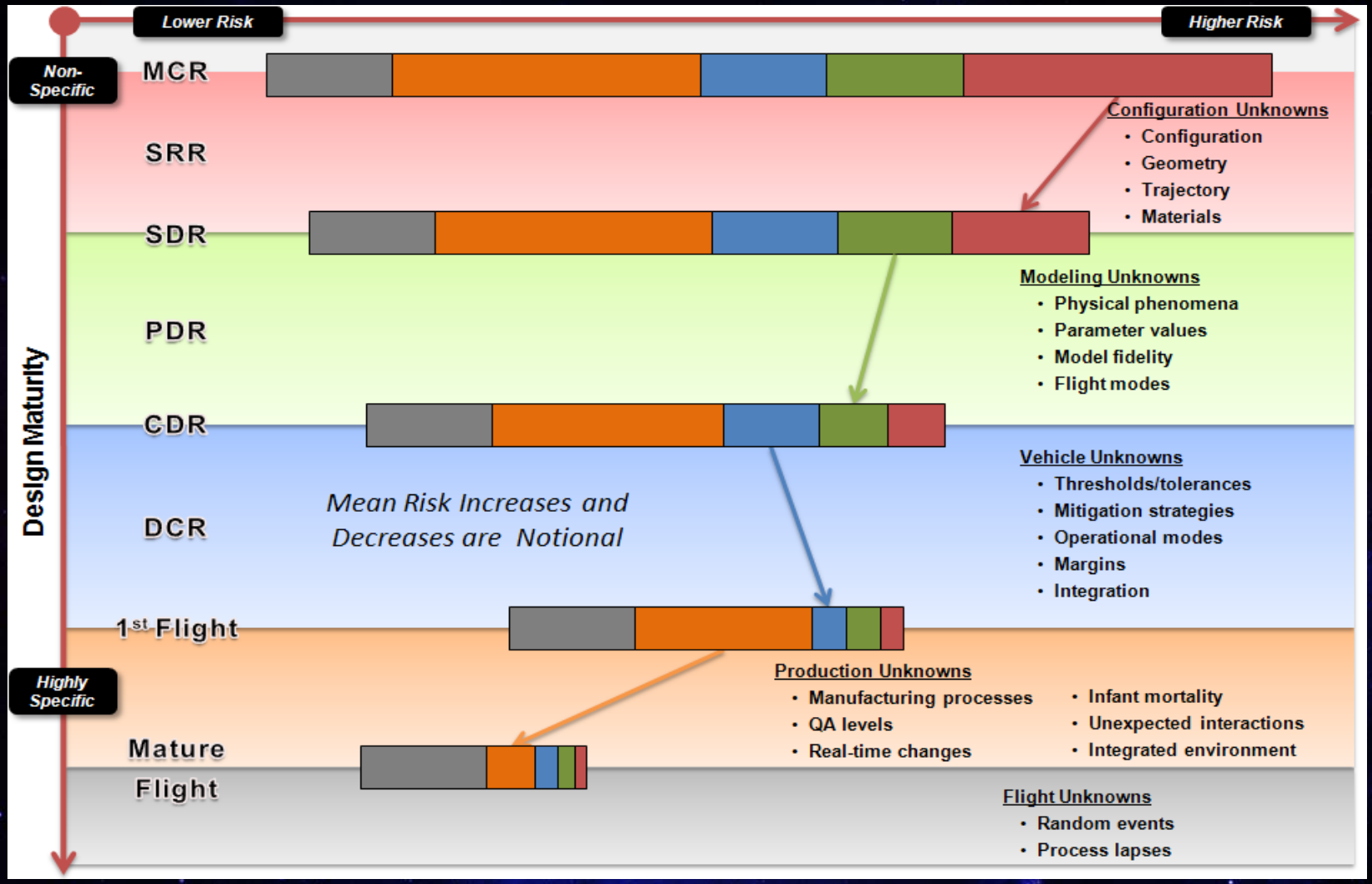
- SLS is using a modified safety review process concurrent or more inline with milestone reviews.
  - Assures products are renewed by independent eyes and key stakeholders
  - Uses Table Tops
  - Top Risks are reported out



Balancing cost, schedule, and technical/safety risk

Proven Processes in the Hands of Experienced Personnel

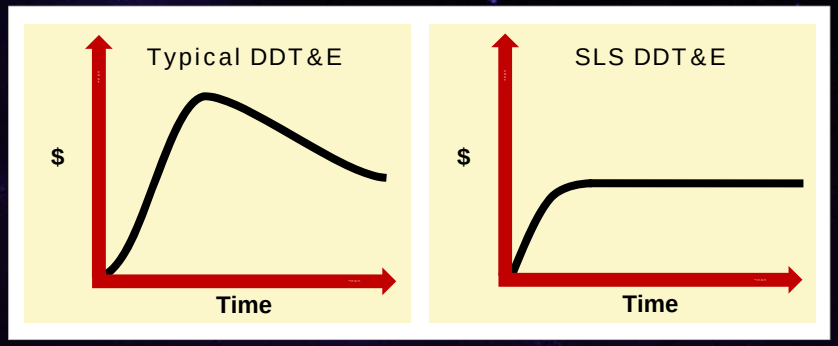
Notional Probability of Failure Uncertainty Decreases with Maturity

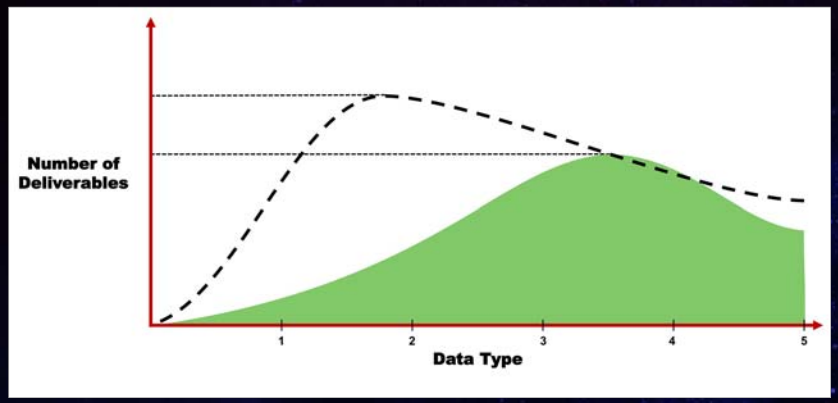


CDR – Critical Design Review
PDR – Preliminary Design Review
DCR – Design Certification Review
SDR – System Definition Review
MCR – Mission Concept Review
SRR – System Requirements Review

Personal Accountability

- Lean, Integrated Teams with Accelerated Decision Making
- Robust Designs and Margins
- Right-Sized Documentation and Standards
- Evolvable Development Approach
- Hardware Commonality
- Risk-Informed Government Insight/Oversight Model



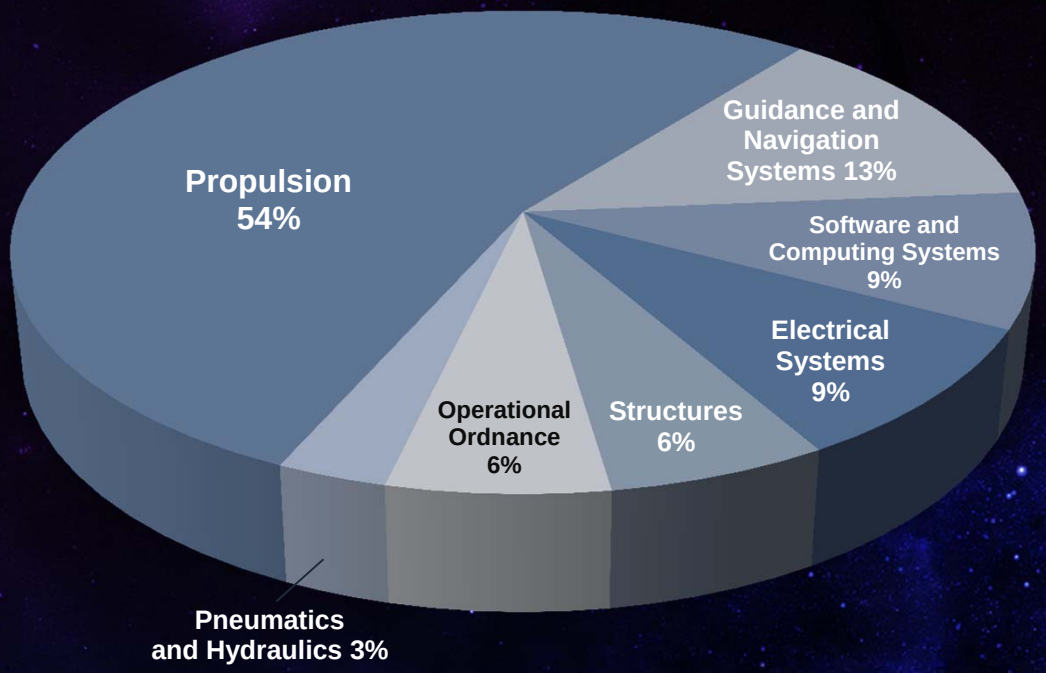


Focuses on the Data Content and Access to the Data

Safe, Affordable, Sustainable

Risk-Based Insight

- **Based on vehicle risk and historic failures, concentrate/augment insight in key areas:**
  - Risk-informed Concentration
    - Propulsion
    - Guidance, Navigation, and Control (GN&C)
    - Avionics
    - Software
    - Electrical
    - Crew Systems
    - Separation Systems
  - Nominal Concentration
    - Power and Thermal
    - Structures
    - Mission Operations
    - Ground Operations
    - Probabilistic
    - Environmental Control and Life Support



1980 – 2007
Worldwide Launch Failure Causes

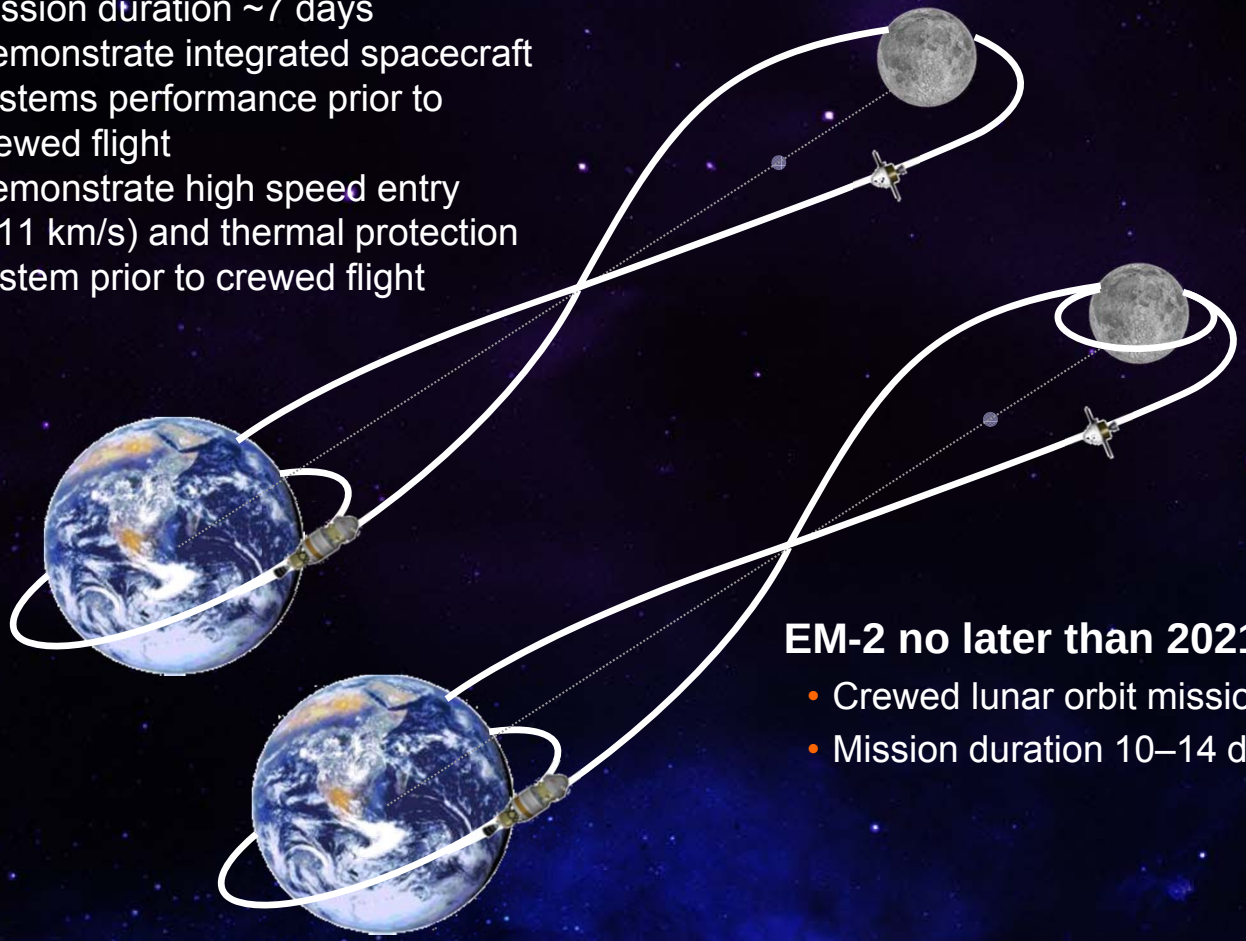
Source: FAA Launch Vehicle Failure Mode Database, May 2007

Focused on Block I Flight in 2017

Initial Exploration Missions (EM)

EM-1 in 2017

- Un-crewed circumlunar flight – free return trajectory
- Mission duration ~7 days
- Demonstrate integrated spacecraft systems performance prior to crewed flight
- Demonstrate high speed entry (~11 km/s) and thermal protection system prior to crewed flight

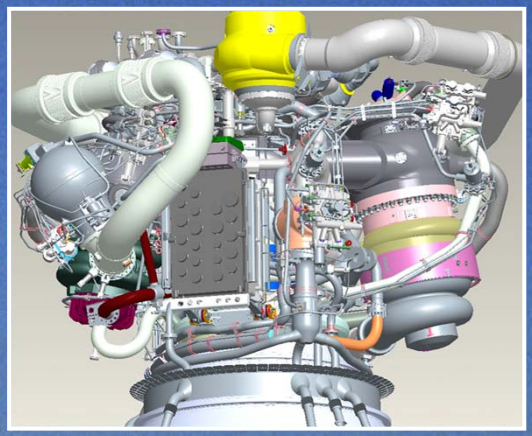


EM-2 no later than 2021

- Crewed lunar orbit mission
- Mission duration 10–14 days

5-Segment Solid Rocket Booster

RS-25 Core Stage Engines In Stock



Common Engine Controller

Interim Cryogenic Propulsion Stage

J-2X Upper Stage Engine

SLS: A Year of Accomplishments

Systems Engineering and Integration SLS model undergoes wind tunnel testing at Langley Research Center Nov 2012

J-2X power pack assembly hot fire test at Stennis Space Center Nov 2012

Multi-Purpose Crew Vehicle Stage Adapter (MSA) Pathfinder Hardware at Marshall Space Flight Center June 2012

Kennedy Space Center Complex 39B ready for a 2017 SLS launch (artist's concept)

RS-25 Engines at Stennis Space Center Oct 2012, shown with future RS-25 Test Stand A1

F-1 engine gas generator hot fire test at Marshall Space Flight Center, Jan 2013 – technology development for an optional Advanced Booster concept

Qualification Motor 1 casting at ATK Oct 2012

System Requirements Review/System Definition Review Completed

The Road to First Flight in 2017

NASA Life Cycle Phases	Approval for Formulation ▼	FORMULATION	▽ Approval for Implementation	IMPLEMENTATION			
Program Life Cycle Phases	Pre-Phase A: Concept Studies	Phase A: Concept & Technology Development	Phase B: Preliminary Design & Technology Completion	Phase C: Final Design & Fabrication	Phase D: System Assembly, Int. & Test, Launch & Checkout	Phase E: Operations & Sustainment	Phase F: Closeout
Program Life Cycle Gates and Major Events	KDP A ✔	KDP B ✔	KDP C	EFT-1 Launch	KDP D KDP E EM-1 Launch	KDP F EM-2 Launch	
Human Space Flight Project Reviews	MCR ✔ 2011	SRR/SDR ✔ 2012	PDR 2013	CDR 2015	SR 2016 FRR 2017	2021	

FOCUSED TOWARD

We don't do a good job… pointing out the monumental effort that has gone into this Program…. I don't think anyone would have thought in September [2011] that this Program might be this far so fast.

Leroy Cain, Chair
Independent Standing Review Board
(NASA Space Shuttle Program Flight Director)
NASA Directorate Program Management Council
June 29, 2012

Going Boldly Beyond

I have great respect for the Marshall Center and the workforce, and the progress with the Space Launch System is but one example of why that respect is well placed.

Vice Admiral Joseph W. Dyer, USN (Ret.)
Chair, NASA Aerospace Safety Advisory Panel
May 2012

For More Information

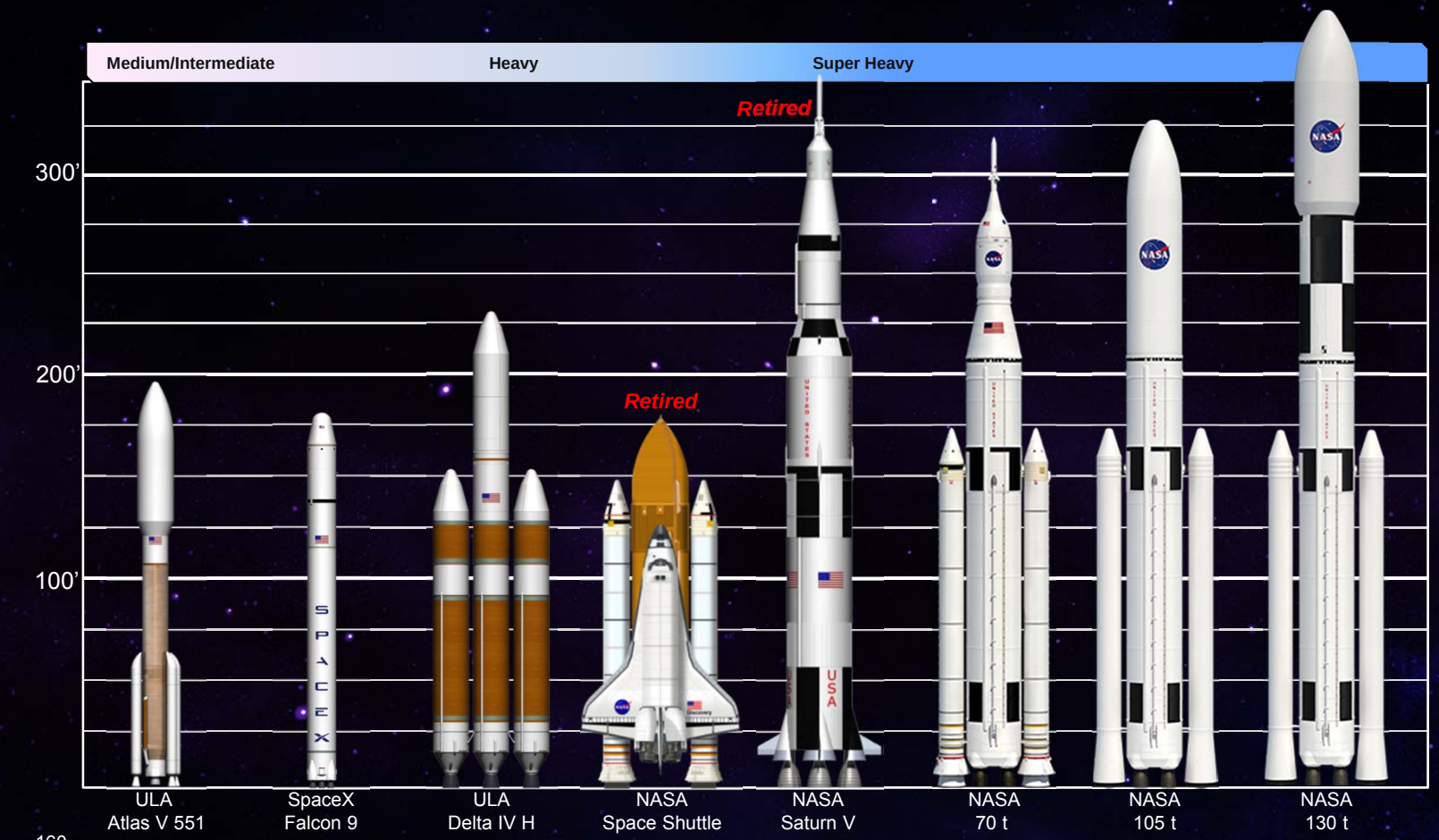
www.nasa.gov/sls

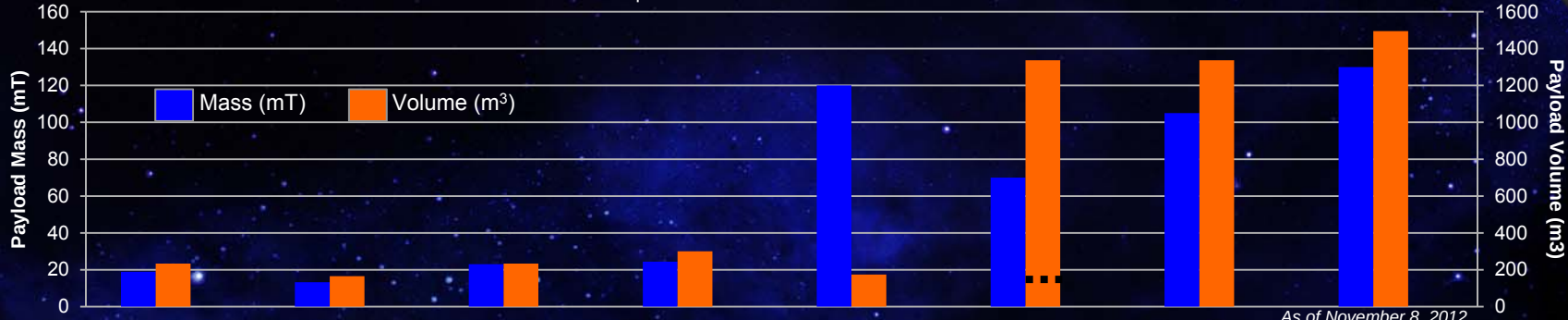
www.twitter.com/nasa_sls

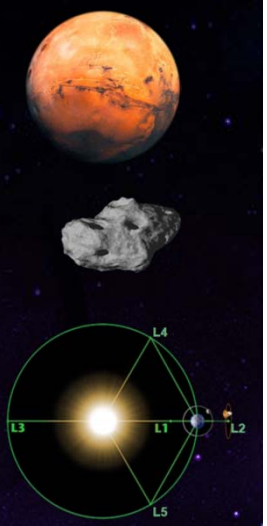
www.facebook.com/nasasls

Back-up info

U.S. Launch Vehicle Fleet







As of November 8, 2012

www.nasa.gov/sls